CLAIMS

What is claimed is:

1. A method for improving turbo code based incremental redundancy, the method comprising the steps of:

puncturing a data stream for a first transmission to provide a set of first unpunctured trellis sections;

puncturing a data stream for a second transmission to provide a set of second unpunctured trellis sections; and

incremental redundancy combining the first and second transmissions of the trellises to provide non-adjacent first and second unpunctured trellis sections.

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2. The method of claim 1, wherein the combining step provides a composite puncturing pattern that is uniformly patterned with unpunctured trellis sections.

3. The method of claim 1, wherein the puncturing steps each provide a set of respective first and second orthogonal unpunctured trellis sections.

4. The method of claim 1, wherein the puncturing steps each include a substep of rate matching each bit stream using a rate matching parameter defined by the equations

$$e_{ini}(r)=\left\{\left[X_i-\left(r\cdot e_{plus}/r_{\max}\right)-1\right]\bmod e_{plus}\right\}+1$$

and

$$e_{ini}(r)=\left\{\left[X_i-\left((s+2\cdot r)\cdot e_{plus}/(2\cdot r_{\max})\right)-1\right]\bmod e_{plus}\right\}+1$$

where $r\in\{0,\cdots,r_{\max}-1\}$ and $r_{\max}$ is the total number of redundancy versions allowed by varying r, wherein e_{ini} is calculated for each bit stream according to the e_{ini} variation parameter r, s is 0 or 1 depending on whether the transmission is non-self-decodable or self-decodable, respectively, e_{plus}, and e_{minus} are chosen according to the table

	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys}-N_{t,sys}\rvert$
Parity 1 RM P1_2	N_{p1}	$a\cdot N_{p1}$	$a\cdot\lvert N_{p1}-N_{t,p1}\rvert$
Parity 2 RM P2_2	N_{p2}	$a\cdot N_{p2}$	$a\cdot\lvert N_{p2}-N_{t,p2}\rvert$

where $a = 2$ for parity 1 and $a = 1$ for parity 2, N_{sys} is the number of systematic bits, N_{p1} is the number of parity 1 bits, N_{p2} is the number of parity 2 bits, $N_{t,sys}$ is the number of transmitted systematic bits, $N_{t,p1}$ is the number of transmitted parity 1 bits, and $N_{t,p2}$ is the number of transmitted parity 2 bits, and wherein rate matching equations are selected from one of the group consisting of: choosing either one of the equations to rate match for both the case of puncturing (i.e., $N_{data}\le N_{sys}+N_{p1}+N_{p2}$) and the case of repetition (i.e., $N_{data}>N_{sys}+N_{p1}+N_{p2}$), and choosing one of the equations to rate match for puncturing and the other equation to rate matching for repetition.

5. The method of claim 1, wherein the puncturing steps each include a substep of rate matching each bit stream using a rate matching parameter defined by the equations

$$e_{ini}(r) = \left\{\left[X_i - \left(r \cdot e_{plus}/2\right) - 1\right] \bmod e_{plus}\right\} + 1$$

in the case of puncturing , i.e., $N_{data} \leq N_{sys} + N_{p1} + N_{p2}$, and

$$e_{ini}(r) = \left\{\left[X_i - \left((2 \cdot s + r) \cdot e_{plus}/4\right) - 1\right] \bmod e_{plus}\right\} + 1$$

for repetition, i.e., $N_{data} > N_{sys} + N_{p1} + N_{p2}$, where r is the e_{ini} variation parameter, s is 0 or 1 depending on whether the transmission is non-self-decodable or self-decodable, respectively, and r ranges from 0 to r_{max} to vary the initial error variable e_{ini}, and X_i , e_{plus}, and e_{minus} are chosen according to the table

	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys} - N_{t,sys}\rvert$
Parity 1 RM P1_2	N_{p1}	$a \cdot N_{p1}$	$a \cdot \lvert N_{p1} - N_{t,p1}\rvert$
Parity 2 RM P2_2	N_{p2}	$a \cdot N_{p2}$	$a \cdot \lvert N_{p2} - N_{t,p2}\rvert$

where $a = 2$ for parity 1 and $a = 1$ for parity 2, N_{sys} is the number of systematic bits, N_{p1} is the number of parity 1 bits, N_{p2} is the number of parity 2 bits, $N_{t,sys}$ is the number of transmitted systematic bits, $N_{t,p1}$ is the number of transmitted parity 1 bits, and $N_{t,p2}$ is the number of transmitted parity 2 bits.

6. The method of claim 5, further comprising a step of selecting a redundancy scheme, wherein:

if Chase redundancy is chosen, setting $s = 1$ and $r = 1$ for all transmissions;

if a partial IR redundancy is chosen, performing the substeps of:

calculating the possible number of unique redundancy versions as

$$r_N = \left\lceil \frac{\sum_{i=1}^{P} N_{p\_i}}{\sum_{i=1}^{P} N_{t\_p\_i}} \right\rceil$$

where N_{p_i} represents the number of parity bits at the output of the turbo encoder from the i^{th} parity stream, $N_{t\_p\_i}$ represents the number of parity bits to be transmitted from the i^{th} parity stream, and P is the number of parity streams, wherein if $r_N > r_{max}$ then $r_N = r_{max}$; and

for transmission index n, from $1,2,\ldots,r_N$, setting $s = 1$ and $r = n$-1, and wherein if $n > r_N$, resetting n to 1 and repeating this substep; and

if a full IR redundancy is chosen, performing the substeps of:

a) calculating the possible number of unique redundancy versions as

$$r_N = \min_k \left[\frac{1}{R} \times k = \frac{1}{BR} \times i \right]$$

where BR is the base code rate, R is the transmit code rate, and k and i are positive integers chosen such that exactly k transmissions equal i systematic and parity output blocks, wherein if $r_N > r_{max}$ then $r_N = r_{max}$;

b) for transmission index $n = 1$, setting $s = 1$, $r = 0$, and $N_t = N_{trans}$, and

c) for transmission index n from $2,\ldots,r_N$, repeating the substeps of:

setting $N_t = N_t + N_{trans}$;

setting $flag = 0$;

if $(N_t \geq \frac{1}{BR} \times N_{sys})$ then setting $flag = 1$ and $(N_t = N_t - \frac{1}{BR} \times N_{sys})$ where N_{sys} is the number of systematic bits generated by the turbo encoder;

setting $s = 0$;

if $((N_t \geq N_{sys}) \& (flag = 1))$ then setting $s = 1$;

setting $r = r + 1$; and

if $n > r_N$, resetting n to 1 and repeating step b).

7. The method of claim 1, further comprising the step of bit priority mapping of systematic bits to position of higher reliability in a modulation constellation.

8. The method of claim 7, wherein the mapping step includes providing an interleaver of size $N_{row} \times N_{col}$, where $N_{row}=log_2(M)$ and $N_{col}=N_{trans}/N_{row}$, where M is the modulation size and N_{trans} is the number of coded and rate-matched bits to be transmitted and the upper rows of the array have a higher priority than the lower rows of the array, and wherein data is read into the interleaver row by row starting in the topmost row, filling the interleaver with all the systematic bits first, followed by the parity bits, and reading data out of the interleaver column by column.

9. The method of claim 8, wherein the interleaver is of size 16x30, and wherein the mapping step includes performing inter-column permutation using the following permutation pattern {0, 20, 10, 5, 15, 25, 3, 13, 23, 8, 18, 28, 1, 11, 21, 6, 16, 26, 4, 14, 24, 19, 9, 29, 12, 2, 7, 22, 27, 17}.

10. The method of claim 1, further comprising the step of transmitting a set of parameters governing a selected incremental redundancy version sequence operable in the puncturing steps, the transmitting step including one of the group consisting of: explicitly specifying the redundancy version parameters and transmitting these parameters using a control channel, and initially transmitting a table of redundancy version parameters and then selecting a table entry as a means of identifying the redundancy version parameters.

11. A method for improving turbo code based incremental redundancy, the method comprising the steps of:

puncturing a data stream for a first transmission to provide an orthogonal set of first unpunctured trellis sections;

puncturing a data stream for a second transmission to provide an orthogonal set of second unpunctured trellis sections; and

incremental redundancy combining the first and second transmissions of the trellises to provide uniformly patterned and non-adjacent first and second unpunctured trellis sections.

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12. The method of claim 11, wherein the puncturing steps each include a substep of rate matching each bit stream using a rate matching parameter defined by the equations

$$e_{ini}(r) = \left\{ \left[X_i - \left(r \cdot e_{plus} / r_{\max} \right) - 1 \right] \bmod e_{plus} \right\} + 1$$

and

$$e_{ini}(r) = \left\{ \left[X_i - \left((s + 2 \cdot r) \cdot e_{plus} / (2 \cdot r_{\max}) \right) - 1 \right] \bmod e_{plus} \right\} + 1$$

where $r \in \{0, \cdots, r_{\max} - 1\}$ and $r_{\max}$ is the total number of redundancy versions allowed by varying r, wherein e_{ini} is calculated for each bit stream according to the e_{ini} variation parameter r, s is 0 or 1 depending on whether the transmission is non-self-decodable or self-decodable, respectively, e_{plus}, and e_{minus} are chosen according to the table

	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys} - N_{t,sys} \rvert$
Parity 1 RM P1_2	N_{p1}	$a \cdot N_{p1}$	$a \cdot \lvert N_{p1} - N_{t,p1} \rvert$
Parity 2 RM P2_2	N_{p2}	$a \cdot N_{p2}$	$a \cdot \lvert N_{p2} - N_{t,p2} \rvert$

where $a = 2$ for parity 1 and $a = 1$ for parity 2, N_{sys} is the number of systematic bits, N_{p1} is the number of parity 1 bits, N_{p2} is the number of parity 2 bits, $N_{t,sys}$ is the number of transmitted systematic bits, $N_{t,p1}$ is the number of transmitted parity 1 bits, and $N_{t,p2}$ is the number of transmitted parity 2 bits, and wherein rate matching equations are selected from one of the group consisting of: choosing either one of the equations to rate match for both the case of puncturing (i.e., $N_{data} \le N_{sys} + N_{p1} + N_{p2}$) and the case of repetition (i.e., $N_{data} > N_{sys} + N_{p1} + N_{p2}$), and choosing one of the equations to rate match for puncturing and the other equation to rate matching for repetition.

13. The method of claim 11, wherein the puncturing steps each include a substep of rate matching each bit stream using a rate matching parameter defined by the equations

$$e_{ini}(r)=\left\{\left[X_i-\left(r\cdot e_{plus}/2\right)-1\right]\bmod e_{plus}\right\}+1$$

in the case of puncturing, i.e., $N_{data} \leq N_{sys}+N_{p1}+N_{p2}$, and

$$e_{ini}(r)=\left\{\left[X_i-\left((2\cdot s+r)\cdot e_{plus}/4\right)-1\right]\bmod e_{plus}\right\}+1$$

for repetition, i.e., $N_{data} > N_{sys}+N_{p1}+N_{p2}$, where r is the e_{ini} variation parameter, s is 0 or 1 depending on whether the transmission is non-self-decodable or self-decodable, respectively, and r ranges from 0 to r_{max} to vary the initial error variable e_{ini}, and X_i, e_{plus}, and e_{minus} are chosen according to the table

	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys}-N_{t,sys}\rvert$
Parity 1 RM P1_2	N_{p1}	$a\cdot N_{p1}$	$a\cdot\lvert N_{p1}-N_{t,p1}\rvert$
Parity 2 RM P2_2	N_{p2}	$a\cdot N_{p2}$	$a\cdot\lvert N_{p2}-N_{t,p2}\rvert$

where $a = 2$ for parity 1 and $a = 1$ for parity 2, N_{sys} is the number of systematic bits, N_{p1} is the number of parity 1 bits, N_{p2} is the number of parity 2 bits, $N_{t,sys}$ is the number of transmitted systematic bits, $N_{t,p1}$ is the number of transmitted parity 1 bits, and $N_{t,p2}$ is the number of transmitted parity 2 bits.

14. The method of claim 11, further comprising a step of determining incremental redundancy parameters s and r, where s is a self-decoding variable and r is a redundancy version, the determining step includes selecting a redundancy scheme, wherein:

if Chase redundancy is chosen, setting $s = 1$ and $r = 1$ for all transmissions;

if a partial IR redundancy is chosen, performing the substeps of:

calculating the possible number of unique redundancy versions as

$$r_N = \left\lceil \frac{\sum_{i=1}^{P} N_{p\_i}}{\sum_{i=1}^{P} N_{t\_p\_i}} \right\rceil$$

where N_{p_i} represents the number of parity bits at the output of the turbo encoder from the i^{th} parity stream, $N_{t\_p\_i}$ represents the number of parity bits to be transmitted from the i^{th} parity stream, and P is the number of parity streams, wherein if $r_N > r_{max}$ then $r_N = r_{max}$; and

for transmission index n, from $1,2,\ldots,r_N$, setting $s = 1$ and $r = n-1$, and wherein if $n > r_N$, resetting n to 1 and repeating this substep; and

if a full IR redundancy is chosen, performing the substeps of:

a) calculating the possible number of unique redundancy versions as

$$r_N = \min_k \left[\frac{1}{R} \times k = \frac{1}{BR} \times i \right]$$

where BR is the base code rate, R is the transmit code rate, and k and i are positive integers chosen such that exactly k transmissions equal i systematic and parity output blocks, wherein if $r_N > r_{max}$ then $r_N = r_{max}$;

b) for transmission index $n = 1$, setting $s = 1$, $r = 0$, and $N_t = N_{trans}$, and

c) for transmission index n from $2,\ldots,r_N$, repeating the substeps of:

setting $N_t = N_t + N_{trans}$;

setting $flag = 0$;

if $(N_t \geq \frac{1}{BR} \times N_{sys})$ then setting $flag = 1$ and $(N_t = N_t - \frac{1}{BR} \times N_{sys})$ where

N_{sys} is the number of systematic bits generated by the turbo encoder;

setting $s = 0$;

if $((N_t \geq N_{sys}) \& (flag = 1))$ then setting $s = 1$;

setting $r = r + 1$; and

if $n > r_N$, resetting n to 1 and repeating step b).

15. The method of claim 11, further comprising the step of bit priority mapping of systematic bits to position of higher reliability in a modulation constellation, wherein the mapping step includes providing an interleaver of size $N_{row} \times N_{col}$, where $N_{row}=log_2(M)$ and $N_{col}=N_{trans}/N_{row}$, where M is the modulation size and N_{trans} is the number of coded and rate-matched bits to be transmitted and the upper rows of the array have a higher priority than the lower rows of the array, and wherein data is read into the interleaver row by row starting in the topmost row, filling the interleaver with all the systematic bits first, followed by the parity bits, and reading data out of the interleaver column by column.

16. The method of claim 15, wherein the interleaver is of size 16x30, and wherein the mapping step includes performing inter-column permutation using the following permutation pattern {0, 20, 10, 5, 15, 25, 3, 13, 23, 8, 18, 28, 1, 11, 21, 6, 16, 26, 4, 14, 24, 19, 9, 29, 12, 2, 7, 22, 27, 17}.

17. A turbo coder with improved incremental redundancy, comprising:

a channel coder operable to code an input data stream into systematic bits and parity bits;

a rate matching block coupled to the channel coder that matches the number of bits at the output of the channel coder to the total number of bits of available HS-DSCH physical channels, the rate matching block punctures a data stream for a first transmission to provide a set of first unpunctured trellis sections and punctures a data stream for a second transmission to provide a set of second unpunctured trellis sections; and

a redundancy version selector coupled to the rate matching block, the redundancy version selector providing rate-matching parameters to the rate matching block, wherein the rate matching block provides incremental redundancy to combine the first and second transmissions of the trellises to provide non-adjacent first and second unpunctured trellis sections.

18. The coder of claim 17, wherein the rate matching block provides a composite puncturing pattern that is uniformly patterned with unpunctured trellis sections.

19. The coder of claim 17, wherein the puncturing steps each include a substep of rate matching each bit stream using a rate matching parameter defined by the equations

$$e_{ini}(r) = \left\{ \left[X_i - \left(r \cdot e_{plus} / r_{\max} \right) - 1 \right] \bmod e_{plus} \right\} + 1$$

and

$$e_{ini}(r) = \left\{ \left[X_i - \left((s + 2 \cdot r) \cdot e_{plus} / (2 \cdot r_{\max}) \right) - 1 \right] \bmod e_{plus} \right\} + 1$$

where $r \in \{0, \cdots, r_{\max} - 1\}$ and $r_{\max}$ is the total number of redundancy versions allowed by varying r, wherein e_{ini} is calculated for each bit stream according to the e_{ini} variation parameter r, s is 0 or 1 depending on whether the transmission is non-self-decodable or self-decodable, respectively, e_{plus}, and e_{minus} are chosen according to the table

	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys} - N_{t,sys} \rvert$
Parity 1 RM P1_2	N_{p1}	$a \cdot N_{p1}$	$a \cdot \lvert N_{p1} - N_{t,p1} \rvert$
Parity 2 RM P2_2	N_{p2}	$a \cdot N_{p2}$	$a \cdot \lvert N_{p2} - N_{t,p2} \rvert$

where $a = 2$ for parity 1 and $a = 1$ for parity 2, N_{sys} is the number of systematic bits, N_{p1} is the number of parity 1 bits, N_{p2} is the number of parity 2 bits, $N_{t,sys}$ is the number of transmitted systematic bits, $N_{t,p1}$ is the number of transmitted parity 1 bits, and $N_{t,p2}$ is the number of transmitted parity 2 bits, and wherein rate matching equations are selected from one of the group consisting of: choosing either one of the equations to rate match for both the case of puncturing (i.e., $N_{data} \le N_{sys} + N_{p1} + N_{p2}$) and the case of repetition (i.e., $N_{data} > N_{sys} + N_{p1} + N_{p2}$), and choosing one of the equations to rate match for puncturing and the other equation to rate matching for repetition.

20. The coder of claim 17, wherein the rate matching parameters are defined by the equations

$$e_{ini}(r)=\{[X_i-(r\cdot e_{plus}/2)-1] \bmod e_{plus}\}+1$$

in the case of puncturing, i.e., $N_{data} \leq N_{sys}+N_{p1}+N_{p2}$, and

$$e_{ini}(r)=\{[X_i-((2\cdot s+r)\cdot e_{plus}/4)-1] \bmod e_{plus}\}+1$$

for repetition, i.e., $N_{data} > N_{sys}+N_{p1}+N_{p2}$, where r is the e_{ini} variation parameter, s is 0 or 1 depending on whether the transmission is non-self-decodable or self-decodable, respectively, and r ranges from 0 to r_{max} to vary the initial error variable e_{ini}, and X_i, e_{plus}, and e_{minus} are chosen according to the table

	X_i	e_{plus}	e_{minus}
Systematic RM S	N_{sys}	N_{sys}	$\lvert N_{sys}-N_{t,sys}\rvert$
Parity 1 RM P1_2	N_{p1}	$a\cdot N_{p1}$	$a\cdot\lvert N_{p1}-N_{t,p1}\rvert$
Parity 2 RM P2_2	N_{p2}	$a\cdot N_{p2}$	$a\cdot\lvert N_{p2}-N_{t,p2}\rvert$

where $a = 2$ for parity 1 and $a = 1$ for parity 2, N_{sys} is the number of systematic bits, N_{p1} is the number of parity 1 bits, N_{p2} is the number of parity 2 bits, $N_{t,sys}$ is the number of transmitted systematic bits, $N_{t,p1}$ is the number of transmitted parity 1 bits, and $N_{t,p2}$ is the number of transmitted parity 2 bits.

21. The coder of claim 20, wherein the redundancy version selector selects a redundancy scheme wherein

if Chase redundancy is chosen, setting $s = 1$ and $r = 1$ for all transmissions;

if a partial IR redundancy is chosen, performing the substeps of:

calculating the possible number of unique redundancy versions as

$$r_N = \left\lceil \frac{\sum_{i=1}^{P} N_{p\_i}}{\sum_{i=1}^{P} N_{t\_p\_i}} \right\rceil$$

where N_{p_i} represents the number of parity bits at the output of the turbo encoder from the i^{th} parity stream, $N_{t\_p\_i}$ represents the number of parity bits to be transmitted from the i^{th} parity stream, and P is the number of parity streams, wherein if $r_N > r_{max}$ then $r_N = r_{max}$; and

for transmission index n, from $1,2,\ldots,r_N$, setting $s = 1$ and $r = n-1$, and wherein if $n > r_N$, resetting n to 1 and repeating this substep; and

if a full IR redundancy is chosen, performing the substeps of:

a) calculating the possible number of unique redundancy versions as

$$r_N = \min_k \left[\frac{1}{R} \times k = \frac{1}{BR} \times i \right]$$

where BR is the base code rate, R is the transmit code rate, and k and i are positive integers chosen such that exactly k transmissions equal i systematic and parity output blocks, wherein if $r_N > r_{max}$ then $r_N = r_{max}$;

b) for transmission index $n = 1$, setting $s = 1$, $r = 0$, and $N_t = N_{trans}$, and

c) for transmission index n from $2,\ldots,r_N$, repeating the substeps of:

setting $N_t = N_t + N_{trans}$;

setting $flag = 0$;

if $(N_t \geq \frac{1}{BR} \times N_{sys})$ then setting $flag = 1$ and $(N_t = N_t - \frac{1}{BR} \times N_{sys})$ where N_{sys} is the number of systematic bits generated by the turbo encoder;

setting $s = 0$;

if $((N_t \geq N_{sys}) \,\&\, (flag = 1))$ then setting $s = 1$;

setting $r = r + 1$; and

if $n > r_N$, resetting n to 1 and repeating step b).

22. The coder of claim 17, further comprising:

a bit priority mapper coupled to the rate matching block, the bit priority mapper operable to map systematic bits to positions of higher reliability in a modulation constellation;

a symbol interleaver coupled to the bit priority mapper, the interleaver operable to load the systematic symbols and parity symbols into an array in a row-wise manner.

23. The coder of claim 22, wherein interleaver provides an array of size $N_{row} \times N_{col}$, where $N_{row}=log_2(M)$ and $N_{col}=N_{trans}/N_{row}$, where M is the modulation size and N_{trans} is the number of coded and rate-matched bits to be transmitted, and the upper rows of the array have a higher priority than the lower rows of the array, and wherein the bit priority mapper provides data into the interleaver row by row starting in the topmost row, filling the interleaver with all the systematic bits first, followed by the parity bits, and wherein the interleaver outputs data column by column.

24. The coder of claim 23, wherein the interleaver is of size 16x30, and wherein the bit mapper performs inter-column permutation using the following permutation pattern {0, 20, 10, 5, 15, 25, 3, 13, 23, 8, 18, 28, 1, 11, 21, 6, 16, 26, 4, 14, 24, 19, 9, 29, 12, 2, 7, 22, 27, 17}.